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DYNAMIC COVERAGE VIA MULTI-ROBOT COOPERATION

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The coverage problem in the context of multi-robot teams can be defined as the maximization of the total area covered by the sensors of all robots in the team. Some coverage algorithms cause a robot group to converge to a static configuration, such that every point under the robots' sensor shadow is covered at every instant of time. We term such a coverage task *static*, since as soon as the desired dispersion is achieved, the system is at equilibrium. For complete static coverage of an environment the robot team should have a certain critical number of robots (depending on environment size, complexity, and robot sensor ranges). Determining the critical number is difficult or impossible if the environment is unknown a priori.

Some applications of coverage (patrolling, for example) do not require every part of the environment to be covered at every instant in time. Imagine a task where a team of robots continually explores the environment but does not settle to a static configuration. This is an example of a *dynamic* coverage task. Note that the *static* coverage problem is a special case of the *dynamic* coverage problem.

There are many applications of autonomous coverage such as tracking unfriendly targets (e.g. military operations), demining or monitoring (e.g. security), and urban search and rescue (USAR) in the aftermath of a natural or man-made disaster (e.g. building rubble due to an earthquake or other causes).

In this paper we address the *dynamic* coverage problem, which requires all areas of free space in the environment to be covered by sensors with as high a frequency as possible, given a fixed number of robots. Our solution to the problem relies on the deployment of beacons (small stationary nodes with radios) into the environment as support infrastructure which the mobile robots use to solve the coverage problem. Robots explore the environment, and based on certain *local criteria*, drop a bea-

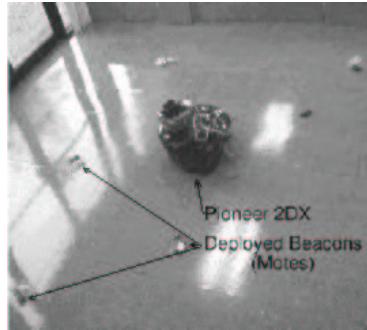


Figure 1. Screen shot of a preliminary experiment involving two platforms: Pioneer 2DX robot, the carrier and a mote, several of which are used as beacons.

con into the environment, from time to time. Each beacon is equipped with a small processor and a radio of limited range. The proposed algorithm is decentralized and performs the coverage task successfully using only local sensing and local interactions between the mobile robots and beacons. The mobile robots interact through the environment by deploying the beacons and changing their state when in the communication vicinity of beacons. The fundamental constraint that we impose on the solution is the lack of global information about the environment (neither a map nor access to global positioning information). We also do not require the robots to be localized. We measure coverage using a *frequency coverage metric* that measures frequency of every-point coverage over time.

We compared our algorithm to a (modified) version of a prior *static* approach. The prior approach, used as a baseline here, was based on robots dispersing themselves in the environment by locally repelling each other in order to 'fan out' and then applying local rules to maximize coverage (we call this the *Molecular* approach).

Simulations show that the *dynamic* algorithm outperforms the *Molecular* approach in cases where the number of robots in the team is less than the critical number. As the environment becomes saturated with mobile robots and the critical number is exceeded the performance of both algorithms, as expected, converges to the same value. In addition, the presented *dynamic* algorithm deploys a static network of nodes into the environment which has applications other than coverage. For example, a problem of recovery of a team of robots from the environment can be solved using the deployed static network of beacons for homing.

At the present time we are conducting real-world experiments to accomplish *dynamic* coverage of a planar bounded environment (Figure 1 shows screen shot of a preliminary experiment). In our experiments we use a team of Pioneer 2DX robots, equipped with 180° laser range finder, wireless communication, compass and a set of beacons. Beacons (motes) have onboard processor and a short range radio.